Proc. 22nd Winter Workshop on
Nuclear Dynamics (2006) 000–000

22nd Winter Workshop
on Nuclear Dynamics
La Jolla, California, USA
March 11–18, 2006

Identified and Inclusive Charged Hadron Spectra from PHENIX

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Abstract. The transverse momentum spectra of charged hadrons are a useful tool in the investigation of particle production in nucleus-nucleus collisions at RHIC. The PHENIX Collaboration has collected and analyzed a variety of data on charged hadrons for different energies and collision species, a summary of which is presented here, with emphasis on the measured nuclear modification factors, which establish the suppression of high p_T hadrons in central nucleus-nucleus collisions, and on the proton to pion ratios, which show an enhancement in baryon production at intermediate p_T.

Keywords: RHIC, PHENIX, relativistic nucleus-nucleus collisions, hadron production, nuclear modification factor, baryon anomaly
PACS: 25.75.Dw

1. Introduction

Collisions of heavy nuclei at relativistic energies, such as the ones at RHIC, provide a unique opportunity for the study of nuclear matter at very high temperatures and energy densities. It is expected that under these conditions matter may enter a state where quarks and gluons are no longer confined into hadrons. The motivation for the experimental program at RHIC is to explore this transition and study the new state of matter that may result from it.

For low transverse momentum (< 2 GeV/c) the p_T distributions measured in Au+Au collisions are well reproduced by hydrodynamical models, which also describe the anisotropy of the produced particle distributions through the elliptic flow amplitude, v_2. Statistical thermal models are able to reproduce the relative abundances of different particle species in this region, with a baryon chemical potential and a chemical freeze-out temperature as parameters. At high p_T (> 4 GeV/c) particle production is expected to be dominated by hard scattering processes that can be calculated by perturbative Quantum Chromodynamics (pQCD). It has however been observed at RHIC [1,2] that the yield of high p_T hadrons in central collisions is suppressed relative to the binary collision scaling that would be expected if the Au+Au collisions were equivalent to a superposition of nucleon-nucleon collisions, i.e., in the absence of medium effects. This suppression is likely to be a result of the energy loss that hard partons suffer as they traverse the hot and dense medium created in the collision [3].

2. Detector Systems and Data Analysis

The PHENIX Central Arms allow for charged particle tracking over the pseudorapidity range $|\eta| < 0.35$ and 180 degrees in azimuthal angle, ϕ. In each arm, particle tracks are recorded by a drift chamber (DC), and 3 layers of pad chambers (PC1-3, PC2 in the West Arm only). Particle identification is obtained from a ring imaging Čerenkov detector (RICH), a time of flight wall (TOF) and the electromagnetic calorimeter (EMCal). Collisions along the beam axis, occurring within 30 cm from the nominal interaction position, are triggered by the Beam-Beam Counters (BBC), placed in the 3-4 pseudorapidity range on both sides of the interaction region. The BBC are also used to determine the collision centrality, and provide reaction place information. A more detailed description of the PHENIX Central Arms can be found in Ref. [4].

The charged hadron track reconstruction is based on information from the DC, PC1-3 and the vertex determined by the BBC. Matching hits in the pad chambers are required, and the resulting tracks are projected back to the collision vertex, through the magnetic field, for momentum determination. The momentum scale is known to better than 0.7%. The charged particle spectrum is then corrected for geometrical acceptance, reconstruction efficiency and momentum resolution using a single-particle GEANT based simulation, and the multiplicity dependence of the reconstruction efficiency is determined by embedding single particle tracks into real collision events.

Particle identification is based on the mass calculation from the measured momentum and velocity obtained from the time-of-flight and path length along the particle's trajectory. The identified charged hadron results presented here were measured using the section of the central arm that contains the TOF detector, which covers 22.5 degrees in azimuth. The TOF timing resolution is $\sigma \approx 103$ ps.

3. Nuclear Modification Factor

In order to compare the yield of produced particles in a nucleus-nucleus collision to the p+p reference measurement it is useful to define the Nuclear Modification Factor, R_{AB} as:

$$R_{AB} = \left(\frac{1}{N_{evt}} \frac{d^2 N^{A+B}}{d\eta dp_T} \right) / \left(\langle T_{AB} \rangle \frac{d^2 \sigma^{p+p}}{d\eta dp_T} \right) \tag{1}$$

where $\langle T_{AB} \rangle$ is the average Glauber nuclear overlap function, $\langle N_{coll} \rangle / \sigma_{inel}^{p+p}$, for a given centrality class. Measurements of R_{AA} in Au+Au collisions at RHIC have shown that at high p_T particle production is suppressed [1, 2], by up to a factor of five in the most central collisions. This suppression is however absent in peripheral Au+Au collisions, and in d+Au collisions, leading to the belief that it is due to final state medium effects. Measurements of two particle azimuthal correlations show that in central Au+Au collisions the "away-side jet" is also suppressed [5, 6], which points to the same scenario of energy loss of hard partons in the dense medium.

The understanding of the origin of the measured suppression can be improved by additional studies of how it depends on geometry and collision energy. The Cu+Cu data collected in Run-5 of RHIC, at three different energies, are ideally suited for these studies. A preliminary charged hadron spectra analysis of the Cu+Cu data set at $\sqrt{s_{NN}} = 200$ GeV was performed using less than 10% of the total Minimum Bias data set recorded by PHENIX during Run-5. This preliminary measurement (Fig.1) reaches up to 4 GeV/c in transverse momentum; in order to extend the measurement to higher p_T a detailed study of background tracks that are incorrectly reconstructed as high momentum charged hadrons is necessary. The systematic errors shown are dominated by the uncertainty on the level of this background contribution. When comparing to Au+Au results for R_{AA} [2], it is seen that for similar average numbers of collision participants, N_{part}, the Cu+Cu and Au+Au results agree quite well, even though they correspond to different collision geometries: central for Cu+Cu and mid-central for Au+Au.

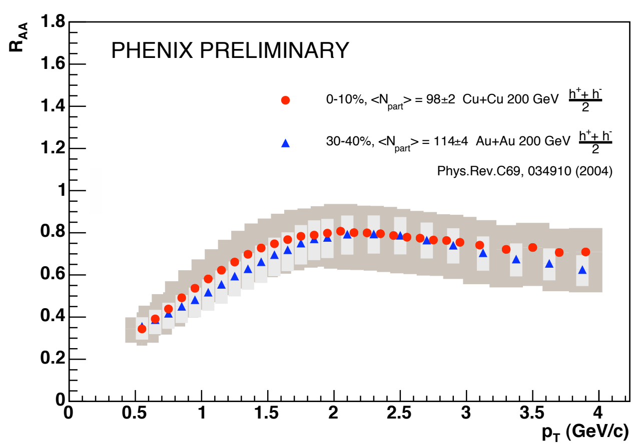

Fig. 1. Comparison between measured R_{AuAu} for collisions in the 30-40% centrality range and R_{CuCu} for the 10% most central collisions. The two centrality regions have similar $\langle N_{part} \rangle$.

Figure 2 shows R_{AuAu} measured by PHENIX [7] in central collisions at $\sqrt{s_{NN}} =$ 200 GeV, for protons, pions and kaons. It is seen that there is a clear difference in the trend as a function of p_T between the protons and the mesons. While the pions and kaons are suppressed, the yield of protons grows with increasing p_T relative to the p+p reference. This difference in behavior is related to the difference seen at intermediate p_T between the R_{AA} of π_0 and charged hadrons [2].

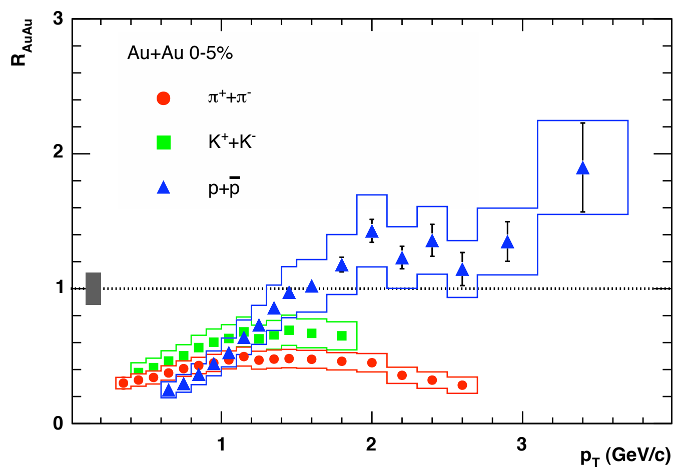

Fig. 2. R_{AuAu} for protons, pions and kaons as a function of p_T in central collisions at $\sqrt{s_{NN}} = 200$ GeV [7].

In central Cu+Cu collisions at $\sqrt{s_{NN}} = 200$ GeV (Fig.3) the situation is similar to the one observed in Au+Au for the R_{AA} of identified hadrons. The N_{part} scaling of R_{AA} seen in Fig.1 applies also to the individual identified hadrons (not shown here), both in terms of magnitude and shape of the p_T dependence.

4. Baryon Anomaly

A surprising result from early on at RHIC was the enhancement of the proton yield relative to the pion yield in central Au+Au collisions for intermediate values of p_T ($\sim$ 2-4 GeV/c) [8, 9]. This observation fits within a more general trend seen in several different measurements, in which baryons and mesons behave differently, regardless of actual particle masses.

Figure 4 shows the proton to pion ratio for Au+Au and Cu+Cu collisions at $\sqrt{s_{NN}} = 200$ GeV as a function of p_T. The enhancement trend for central

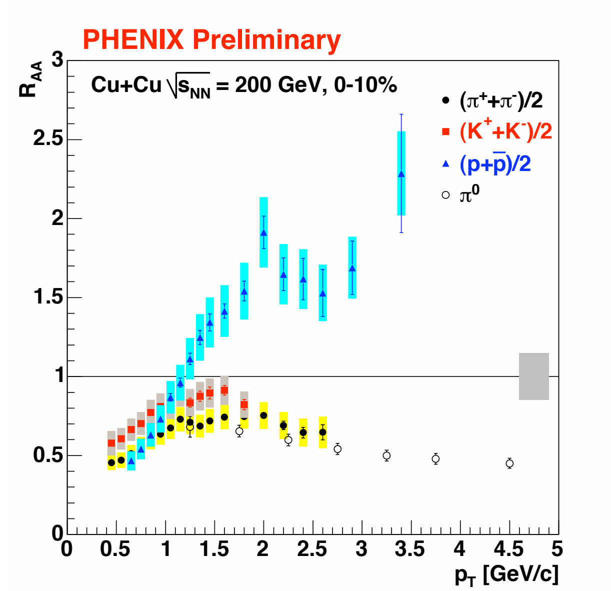

Fig. 3. R_{CuCu} for protons, pions and kaons as a function of p_T in central collisions at $\sqrt{s_{NN}} = 200$ GeV.

collisions is seen for both systems, even though the magnitude is significantly higher in Au+Au. Results from this analysis [10] also indicate that the N_{part} scaling seen for R_{AA} applies to this observable as well, i.e., the results for Cu+Cu and Au+Au at equivalent average N_{part} are very similar.

In order to explain the proton to pion ratio and other measurements for baryons at intermediate p_T, it has been suggested [11–13] that in this region the recombination of quarks into hadrons may be an efficient mechanism of hadron production, when compared to fragmentation (which dominates at higher p_T). Extension of the present measurements of p/π^+ ($\bar{p}/\pi^-$) to higher p_T will provide additional constraints to theoretical models which include recombination, since its effect is expected to decrease at higher p_T, therefore decreasing the proton enhancement.

5. Summary

A sampling of recent results from PHENIX on charged hadron production in Au+Au and Cu+Cu collisions has been presented. Suppression of high p_T charged hadrons is present for both collision systems, but results for identified hadrons show that at intermediate p_T only mesons are suppressed. For protons, an enhancement is seen,

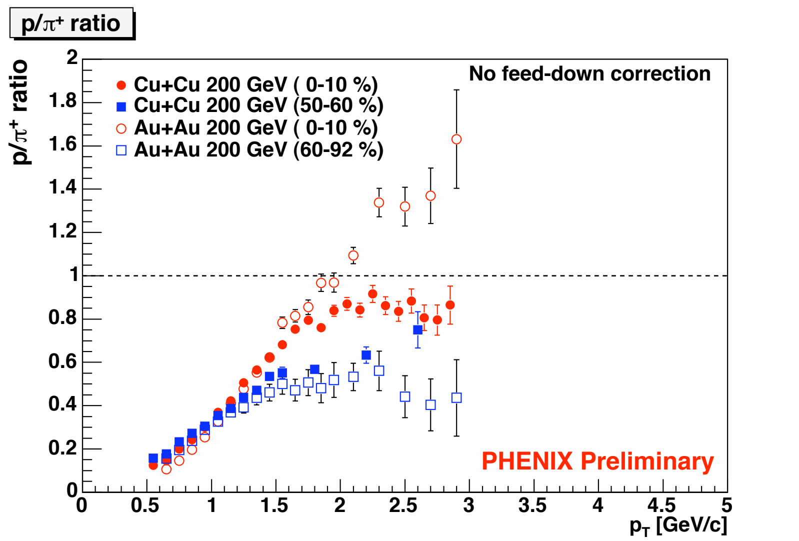

Fig. 4. p/π^+ as a function of p_T for Au+Au and Cu+Cu collisions at $\sqrt{s_{NN}}$ = 200 GeV, for central and peripheral collisions.

both relative to the p+p reference, and to the yield of pions in the same collisions. When comparing Au+Au to Cu+Cu results for $\sqrt{s_{NN}} = 200$ GeV, it is seen that both R_{AA} and particle ratios show N_{part} scaling.

References

1. K. Adcox *et al.* (PHENIX Collaboration), *Phys. Rev. Lett.* **88** (2002) 022301.
2. S. S. Adler *et al.* (PHENIX Collaboration), *Phys. Rev. C* **69** (2004) 034910.
3. X. N. Wang and M. Gyulassy, *Phys. Rev. Lett.* **68** (1992) 1480.
4. K. Adcox *et al.* (PHENIX Collaboration), *Nucl. Instrum. Methods* **A499** (2003) 469.
5. C. Adler *et al.* (STAR Collaboration), Phys. Rev. Lett. **90** (2003) 082302.
6. S. S. Adler *et al.* (PHENIX Collaboration), Phys. Rev. Lett. **97** (2006) 052301.
7. S. S. Adler *et al.* (PHENIX Collaboration), *Phys. Rev. C* **74** (2006) 024904.
8. K. Adcox *et al.* (PHENIX Collaboration) *Phys. Rev. Lett.* **88** (2002) 242301.
9. S. S. Adler *et al.* (PHENIX Collaboration), *Phys. Rev. Lett.* **91** (2003)172301.
10. M. Konno (PHENIX Collaboration), to appear in the proceedings of Quark Matter 2005, arXiv:nucl-ex/0510022

11. R. J. Fries, B. Muller, C. Nonaka and S. A. Bass, *Phys. Rev. C* **68** (2003) 044902.
12. V. Greco, C. M. Ko and P. Levai, *Phys. Rev. Lett.* **90** (2003) 202302.
13. R. C. Hwa and C. B. Yang, *Phys. Rev. C* **70** (2004) 024905.